



# INTERFERENCE ASSESSMENT AND MITIGATION TECHNIQUES FOR EARTH EXPLORATION SATELLITES OPERATING IN THE BAND 8025 – 8400 MHz

Manfred Otter and Edoardo Marelli - European Space Agency

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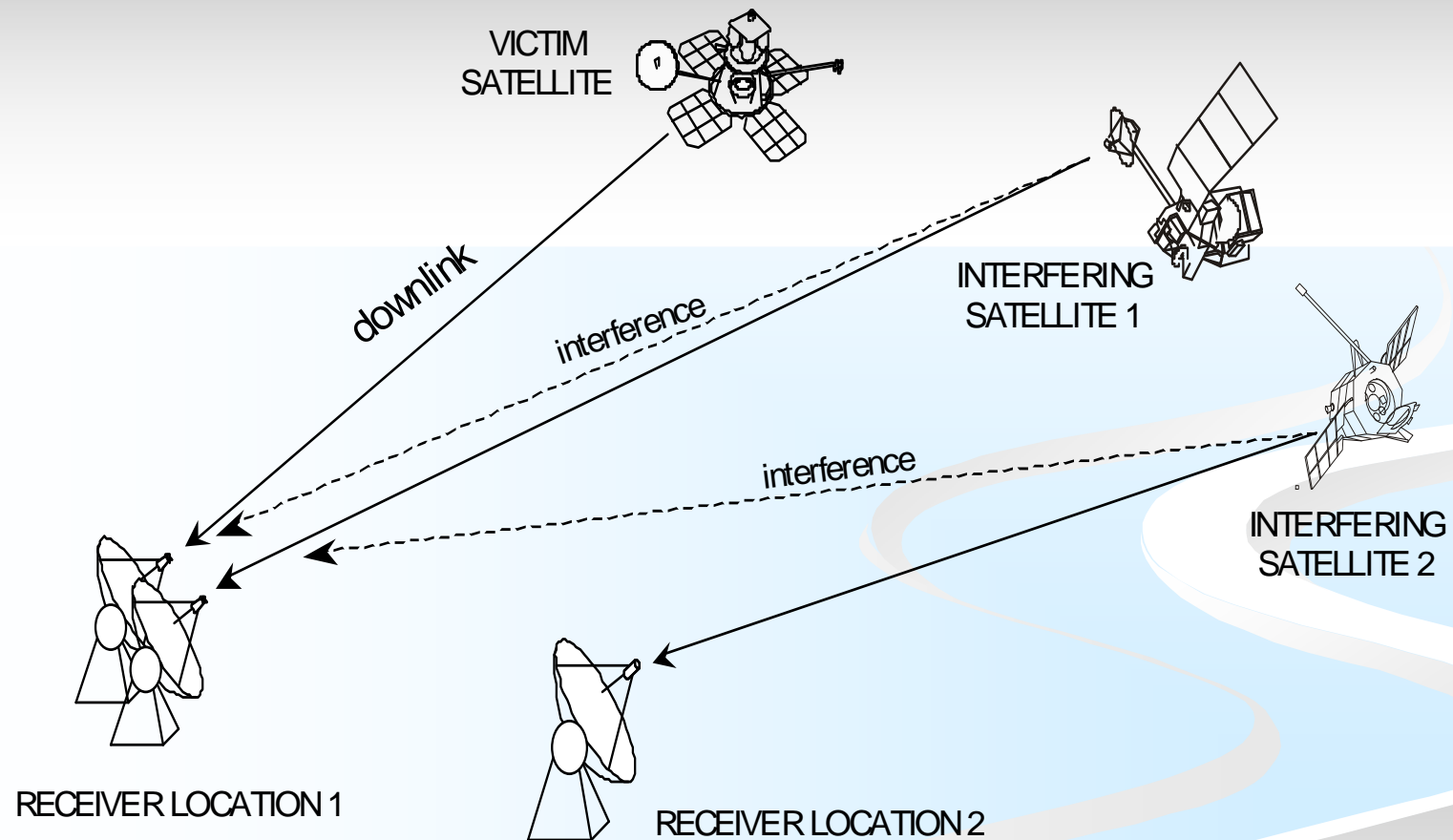
## **BACKGROUND**

- **MOST EARTH OBSERVATION SPACECRAFT OPERATE IN THE FREQUENCY BAND 8025 - 8400 MHz (X-BAND)**
- **SIGNIFICANT INCREASE OF SATELLITES OVER THE PAST DECADE LEADING TO CONGESTION IN THIS BAND**
- **SFCG IDENTIFIED A NEED TO INVESTIGATE INTERFERENCE SCENARIOS AND METHODS TO FACILITATE FUTURE USE OF THIS BAND**
- **SEVERAL STUDIES TAKING INTO ACCOUNT VARIOUS INTERFERENCE MITIGATION TECHNIQUES WERE CONDUCTED**

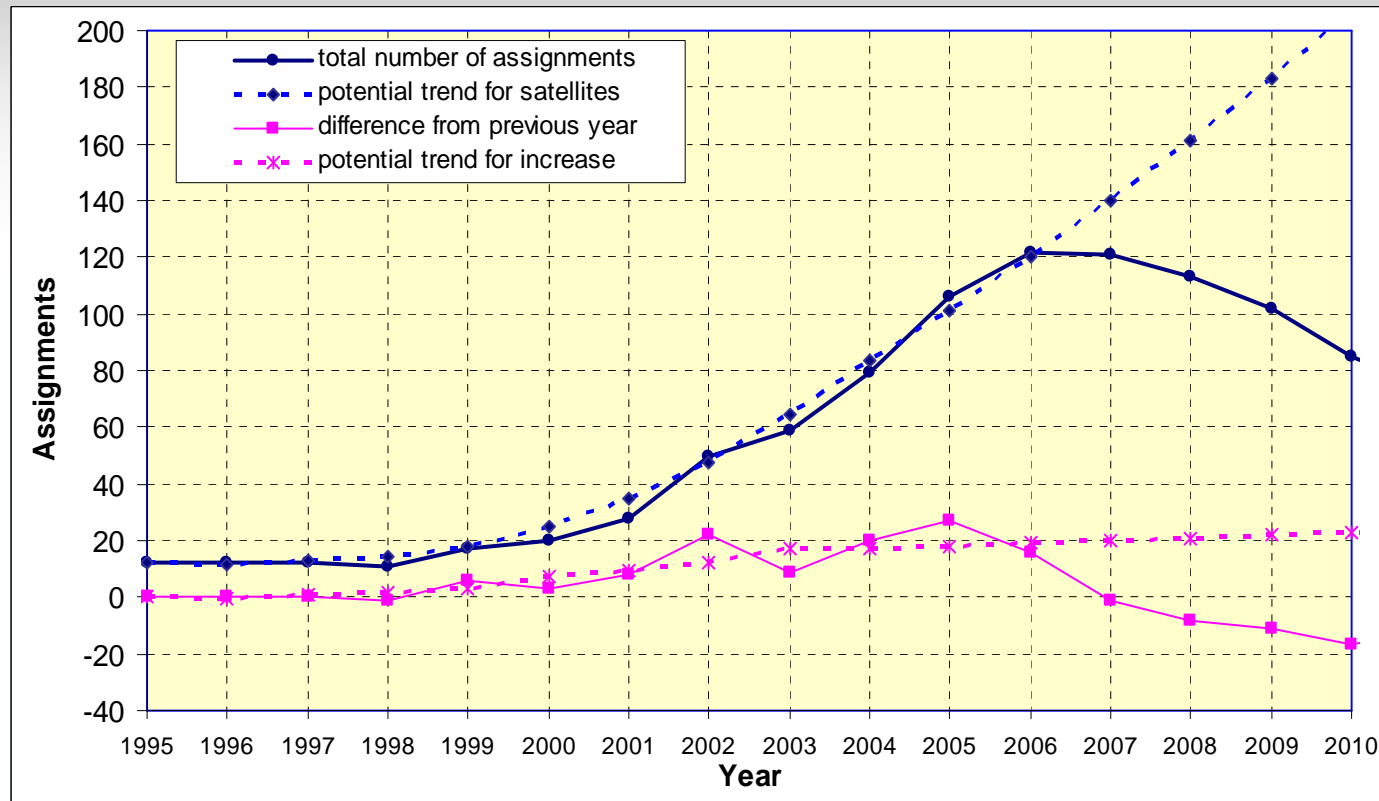
## STUDY OBJECTIVES

- **DETERMINATION OF INTERFERENCE PROBABILITIES FOR CURRENT AND FUTURE DEPLOYMENT SCENARIOS TAKING INTO ACCOUNT SUITABLE INTERFERENCE MITIGATION TECHNIQUES SUCH AS**
  - **ORBITAL PHASING OF SUN-SYNCHRONEOUS SATELLITES**
  - **EARTH STATION DIVERSITY AND GEOGRAPHICAL SEPARATION**
  - **EARTH STATION DIAMETER AND ANTENNA PATTERNS**
  - **AVOIDANCE OF CONTINUOUS TRANSMISSIONS**
  - **SATELLITE ANTENNA TYPES (PARABOLIC, ISOFLUX)**
  - **HOMOGENEOUS DEPLOYMENT OF SATELLITE NETWORKS**
  - **BANDWIDTH EFFICIENT MODULATION AND CODING TECHNIQUES**
  - **POLARISATION DISCRIMINATION**

## TYPICAL INTERFERENCE CONFIGURATIONS



## TOTAL NUMBER OF FREQUENCY ASSIGNMENTS



Source: EESS Data Base Version July 2004

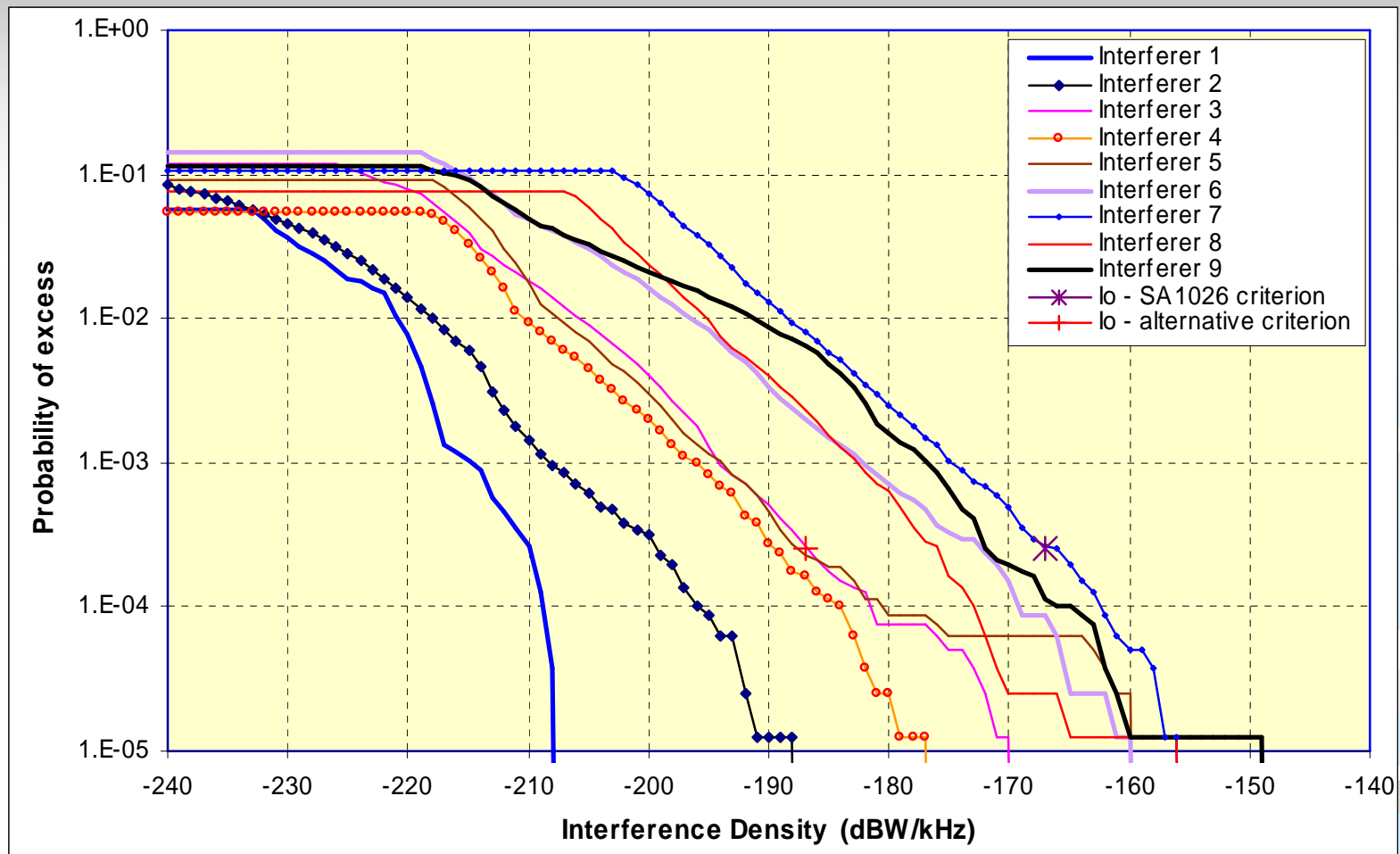
## SIMULATION ASSUMPTIONS

- **SELECTION OF 10 HYPOTHETICAL SATELLITES BASED ON TYPICAL RECORDS EXTRACTED FROM THE DATA BASE**
- **CONSIDERATION OF TWO PROTECTION CRITERIA**
  - -197 dBW/Hz for 0.025% of time based on Recommendation ITU-R SA.1026
  - -217 dBW/Hz based on 150 K and C/I = 10 dB (closer to realistic conditions)
- **SIMULATION DURATION OF 100 DAYS WITH CALCULATIONS DONE AT 10 SECONDS INTERVALS**

## REPRESENTATIVE SET OF SATELLITES PARAMETERS

	SAT-1	SAT-2	SAT-3	SAT-4	SAT-5	SAT-6	SAT-7	SAT-8	SAT-9	SAT-10
Apogee (km)	781	817	705	690	705	450	789	600	822	680
Perigee (km)	769	817	705	673	705	450	789	600	822	680
Inclination (degrees)	98.5	98.7	98.2	98.4	98.2	97.2	98.6	97.7	98.7	82
Right ascension (degrees)	330	220	204.5	337.5	330	157.5	300	345	337.5	270
Transmitter power (dBW)	12	14.5	12.5	1.2	13	3.8	0	7.5	13	3.4
Antenna gain (dBi)	7	7	8	29.6	8.2	24.7	26	6.5	6	29.6
Antenna type	card.	card.	card.	dish	card.	dish	dish	card.	card.	dish
Broadcast mode	no	yes	yes/no	yes	no	no	no	no	no	no
Bandwidth (MHz)	100	85	15/150	320	75	320	100	115	50	320
Ground station	Kiruna	Banga- lore	Kiruna	Fair- banks	Sval- Bard	Kiruna	Kiruna	Kiruna	Sval- bard	Kiruna

## INTERFERENCE PROBABILITIES OF INDIVIDUAL SATELLITES

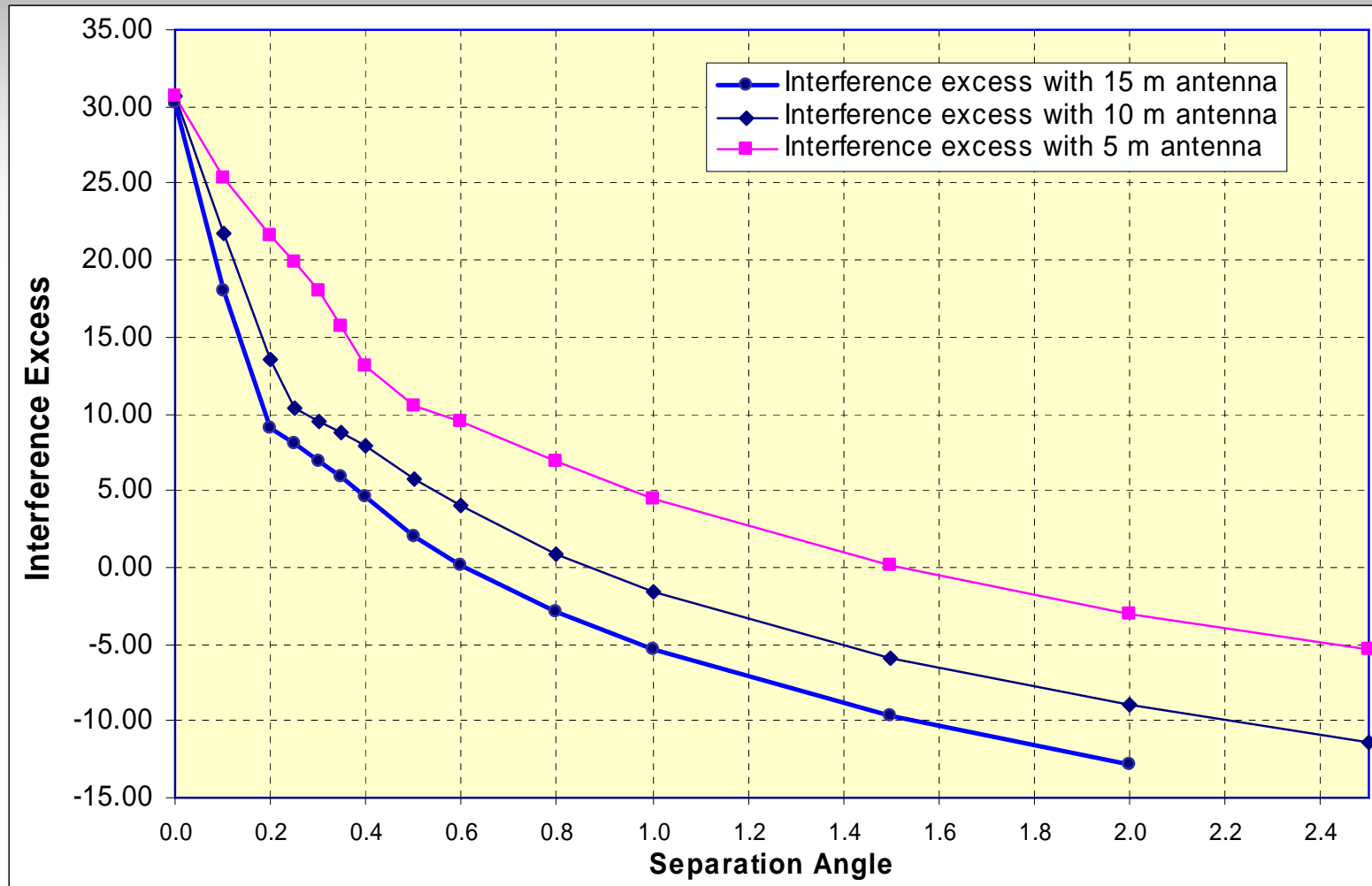




## ORBITAL PHASING

- **TWO SATELLITES WITH SIMILAR ORBIT PARAMETERS BUT OFFSET IN TRUE ANOMALY (MAINLY FOR SUN-SYNCHRONEOUS SATELLITES)**
- **SMALL ORBITAL SEPARATIONS RESULT IN SIGNIFICANT INTERFERENCE REDUCTION**
  - 0.6 degrees to achieve 30 dB interference reduction for a 15 m earth station
  - 0.9 degrees to achieve 30 dB interference reduction for a 10 m earth station
  - 1.5 degrees to achieve 30 dB interference reduction for a 5 m earth station
- **1 DEGREE OF SEPARATION CORRESPONDS TO ONLY AROUND 30 SECONDS SEPARATION TIME**
- **OPERATIONS COORDINATION REQUIRED**

## ORBITAL PHASING

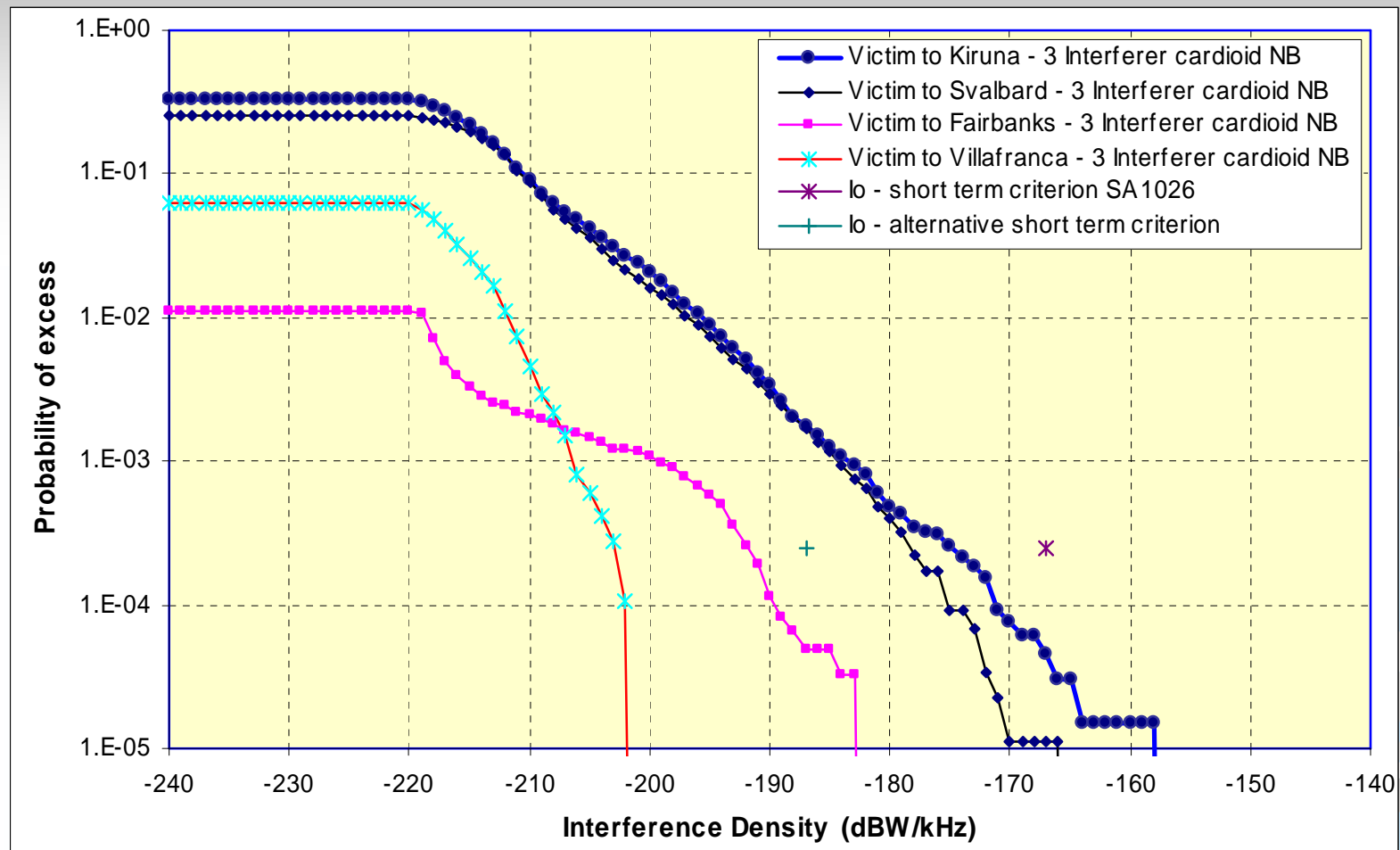


## EARTH STATION DIVERSITY / GEOGRAPHICAL SEPARATION

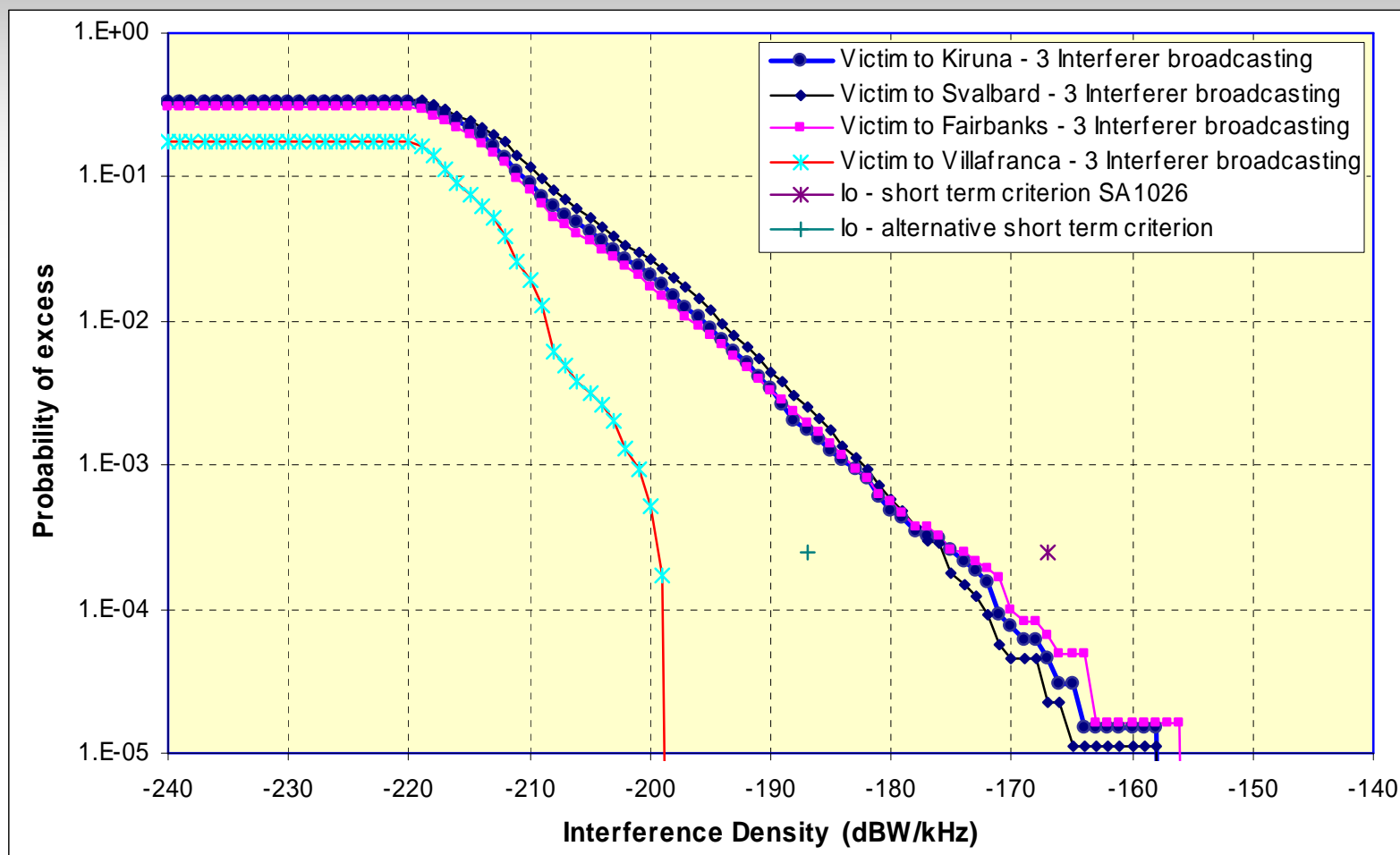
### ■ 3 INTERFERER WITH IDENTICAL BUT VARYING RF PARAMETERS

	Victim	Interferer-1	Interferer-2	Interferer-3
Apogee (km)	781	600	700	800
Perigee (km)	769	600	700	800
Inclination (degrees)	98.5	97.7	98.2	98.6
Right ascension (degrees)	330	345	270	300
Transmitter power (dBW)	13/0	13/0	13/0	13/0
Antenna gain (dBi)	0/20	0/20	0/20	0/20
Antenna type	card./dish	card./dish	card./dish	card./dish
Broadcast mode	no	yes/no	yes/no	yes/no
Bandwidth (MHz)	100	100	100	100
Earth station diameter (m)	5/10/15	5/10/15	5/10/15	5/10/15
Earth station locations	Kiruna, Svalbard, Fairbanks, Villafranca	Kiruna	Kiruna	Kiruna

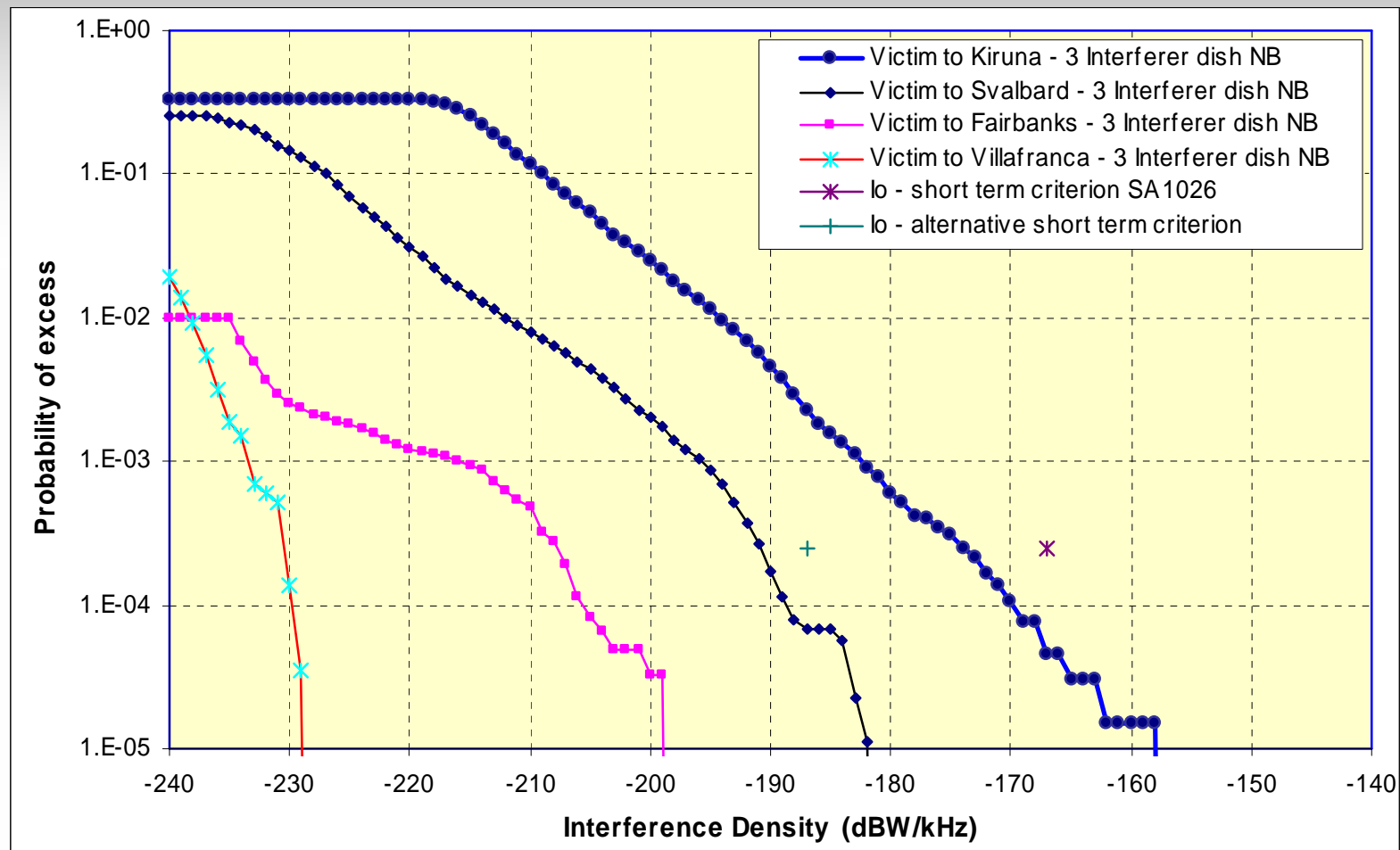
## VARIOUS EARTH STATION LOCATIONS INTERFERER WITH CARDIOID ANTENNAS – NO BROADCAST



## VARIOUS EARTH STATION LOCATIONS INTERFERER WITH CARDIOID ANTENNAS – BROADCAST MODE

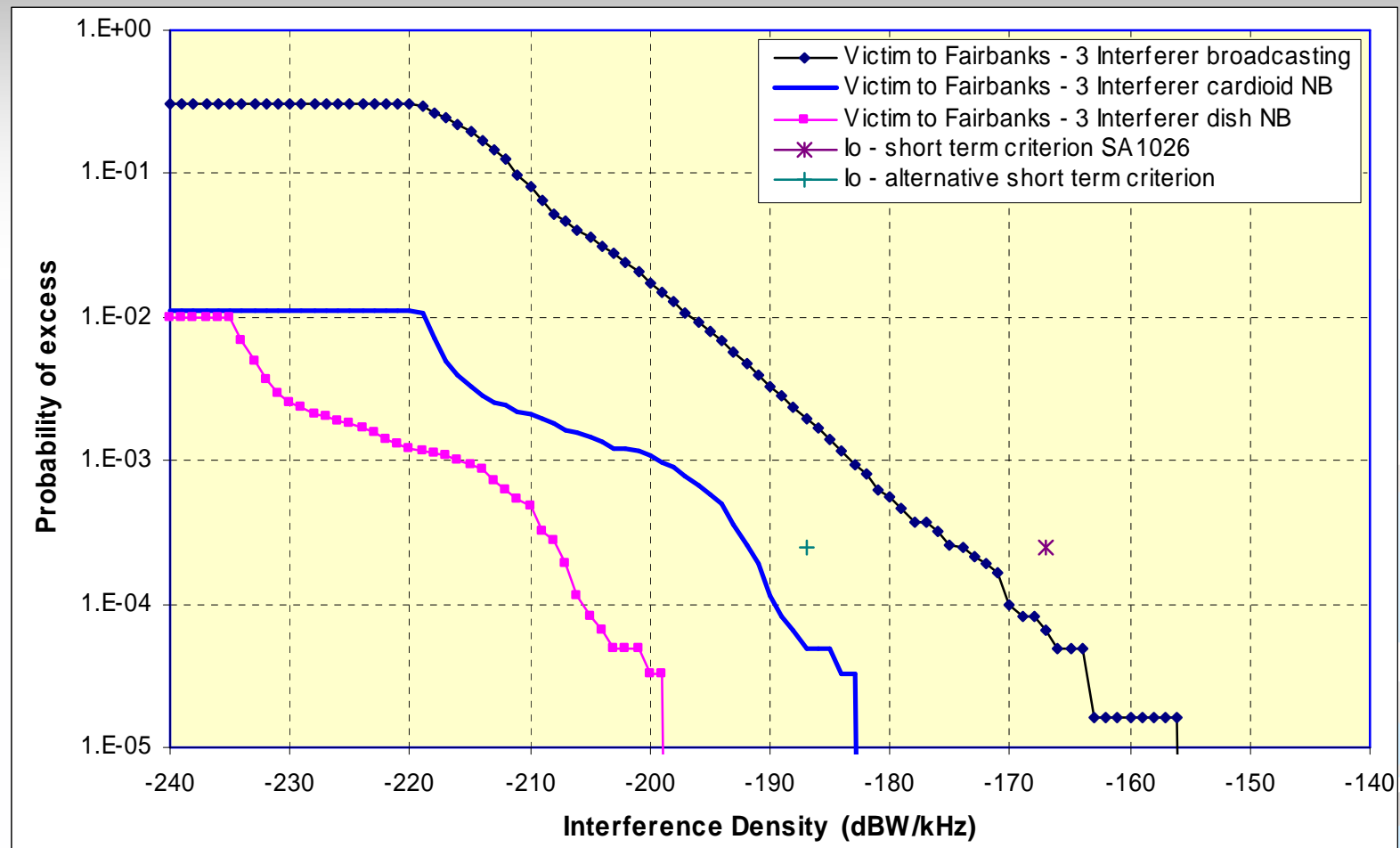


## VARIOUS EARTH STATION LOCATIONS INTERFERER WITH PARABOLIC ANTENNAS – NO BROADCAST



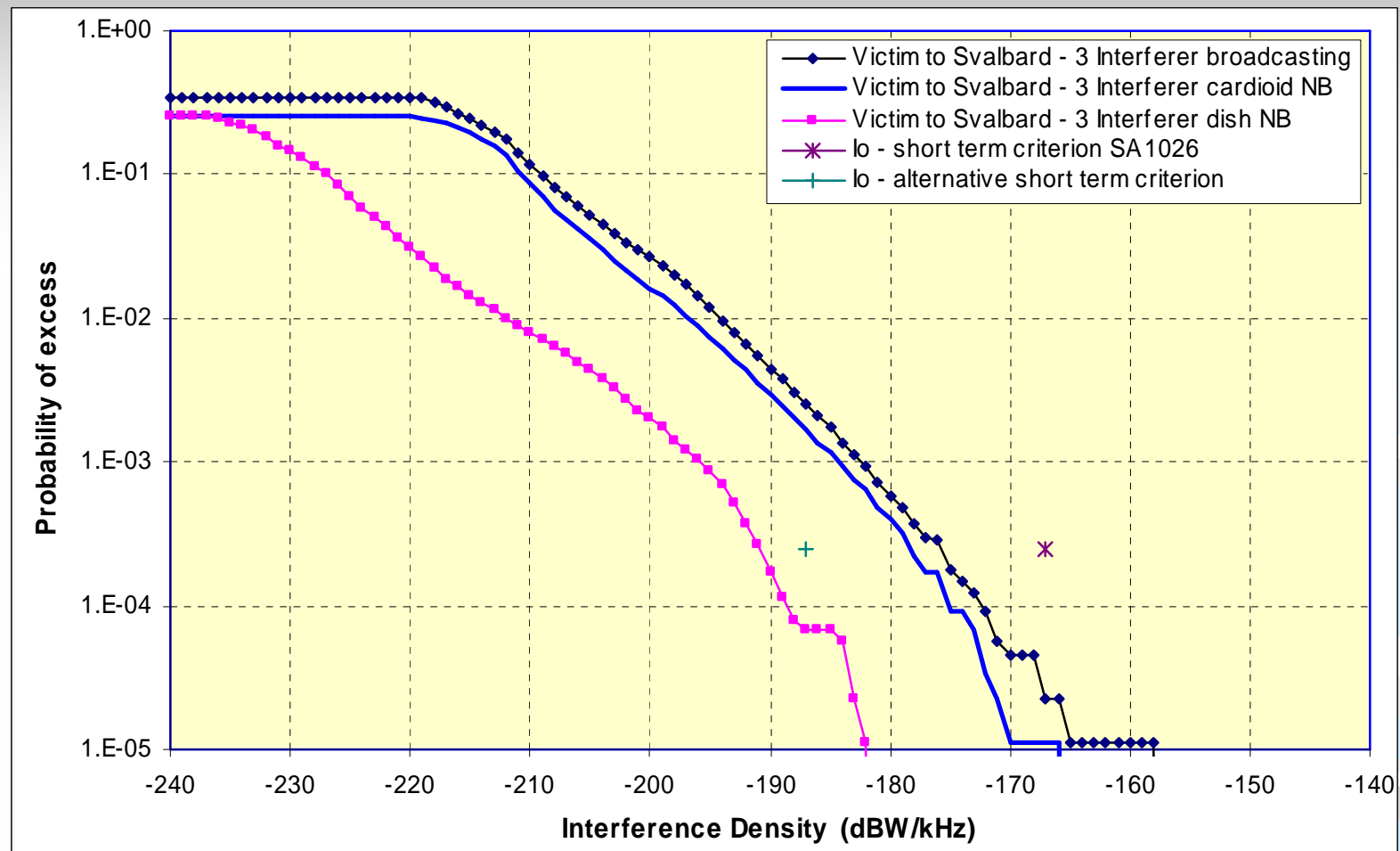
## ANTENNA TYPES AND TRANSMISSION MODES

### LARGE GEOGRAPHICAL SEPARATION OF EARTH STATIONS



# ANTENNA TYPES AND TRANSMISSION MODES

## SMALL GEOGRAPHICAL SEPARATION OF EARTH STATIONS





## CONCLUSIONS (1)

- **ORBITAL PHASING IS A VERY ATTRACTIVE INTERFERENCE MITIGATION TECHNIQUE IN CASES WHERE ORBITS ARE SIMILAR AND CONTINUOUS OPERATION COORDINATION IS FEASIBLE (MOSTLY SUN-SYNCHRONEOUS SATELLITES)**
- **BROADCAST MODES CAUSE HIGH LEVELS OF INTERFERENCE AND SHOULD BE AVOIDED OR AT LEAST CONCENTRATED IN A DEDICATED SUB-BAND**
- **PARABOLIC SATELLITE ANTENNAS WILL SIGNIFICANTLY REDUCE INTERFERENCE**
- **GEOGRAPHICAL SEPARATION OF EARTH STATIONS OR EARTH STATION DIVERSITY CAN ALSO RESULT IN SIGNIFICANT INTERFERENCE REDUCTION**

## CONCLUSIONS (2)

- **OTHER RECOMMENDABLE INTERFERENCE MITIGATION TECHNIQUES NOT CONSIDERED BY THIS STUDY BUT ADDRESSED IN OTHER SFCG STUDIES ARE**
  - **HOMOGENEOUS DEPLOYMENT OF SATELLITE NETWORKS**
  - **BANDWIDTH EFFICIENT MODULATION AND CODING TECHNIQUES**
  - **POLARISATION DISCRIMINATION**
  
- **FUTURE PROJECTS SHOULD CONSIDER THE AVAILABILITY OF THE FREQUENCY BAND 25.5 – 27.0 GHz**
  - **WIDE BANDWIDTH**
  - **HIGHER DISCRIMINATION FOR PARABOLIC ANTENNAS**
  - **POTENTIAL SUPPORT VIA DATA RELAY NETWORK**